Luther Burbank's Contributions to Walnuts

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***Abstract*. Luther Burbank began making controlled crosses between walnut species in the late 19th century after hearing about a "supposed natural European hybrid walnut." He crossed *Juglans hindsii* (northern California black walnut) × *J. regia* (Persian walnut) and produced progeny that he named 'Paradox' because of its extremely fast growth and other "anomalies." He also crossed two American species, *J. hindsii* × *J. nigra* (eastern black walnut), producing 'Royal' walnut progeny that were fast-growing and prolific nut producers. A third interspecific hybrid was a cross between *J. ailantifolia* (Japanese walnut) × *J. regia* that resulted in extremely vigorous progeny but was not named. He observed segregation in the F_2 populations and described giants and dwarfs as reversions to ancestral forms. Luther Burbank also made selections for walnut scion cultivars and was especially interested in thin-shelled nuts. He collected seeds from a *J. regia* growing in San Francisco because it produced regularly and had very high-quality nuts with relatively thin but poorly sealed shells. He selected one of its seedlings as 'Santa Rosa Soft-Shell' and described it as bearing large crops of nuts that were nearly white with thin shells and delicious white meat. Burbank's contributions to the walnut industry endure to this day, especially through the widespread use of seedling and clonal 'Paradox' walnut rootstocks.**

Luther Burbank's field notes published in a 12-volume monographic series (Whitson et al., 1914, 1915) covers 40 years of his plant breeding work. Based on the changes in Burbank's writings about Mendelian genetics in the walnut chapters in Volumes 2 and 11, the notes were likely published consecutively. He wrote that the paper by Mendel (1865) was forgotten for over 30 years (Whitson et al., 1914, 1915). By that time he had been breeding plants in California for more than 20 years. His understanding of Mendelian concepts, although murky, developed somewhat and he ultimately found it useful to explain the performance of his F_1 and F_2 generations.

In his field notes about walnuts published in 1914, Burbank showed that he was aware of Mendel's findings and mentioned "prepotency or dominance" when describing traits of one parent manifesting itself over those of the other in the walnut F_1 interspecific hybrids. When describing the segregation in the F_2 generations, he did not use the term "segregation," rather he called this a "mixture of racial strains."

After describing dwarf walnuts in F_2 populations generated from *J. hindsii* × *J. regia* (or *J. hindsii* × *J. nigra*) F_1 hybrids, Burbank mentioned that Mendel would call them "pure recessives" or homozygous. He followed this with: "The reader may or may not feel that the new terminology adds to our comprehension of the phenomena" (Whitson et al., 1914, 1915, p. 160). However, on page 150, Luther Burbank described the "dwarfs" in the F_2 generation as a "reversion to dwarfed ancestral strains." For the "giants" in the F_1 and F_2 generations, he wrote: "These, then are the remote ancestors ("colossal plants of the Carboniferous Era") that may be invoked in explanation of the rapid growth and relatively gigantic stature of our hybrid walnuts" (p. 164).

By the time that he wrote the field notes published in Vol. 11 of the same series (Whitson et al., 1914, 1915), Luther Burbank was applying Mendelian terminology to his walnut populations. At this time, he was using the term "segregation" and wrote: "It will be noted also that the distribution of these characters in the second generation was essentially that which has come to be familiar everywhere within recent years as the typical distribution of characters among second generation hybrids in what is now known as Mendelian heredity" (Whitson et al., 1914, 1915, p. 195).

The segregation that he observed in the F_2 generation from 'Paradox' was first described in his 1898 supplementary catalog (Whitson et al., 1914, 1915). In this catalog, he divided the offspring into three groups: one-third a new type of Persian walnut with broad leaflets, one-third a new type of California black walnut, and the remaining one-third had combined traits of *J. hindsii* and *J. regia*. Burbank wrote that these observations of segregation were obviously made before the catalog was published in 1898 "at a time, therefore, when no one living had the remotest knowledge of the discovery made by Mendel more than thirty years before" (Whitson et al., 1914, 1915, p. 196). At this point, he seemed defensive: "…the fact being quite overlooked that the essential principles involved had been discovered by me quite independently; exploited by me in connection with many hundreds of species; given publication by me prior to the rediscovery of Mendel's forgotten paper: championed by me against the opposition of all the leading authorities of the world; and that therefore the aspect of heredity in question might with full propriety have been named "Burbankian" instead of "Mendelian," were it not that Mendel's discovery had priority because it was published so long ago as 1863, whereas my independent discovery of the principle was not made until almost twenty years later. Even at that, however, I had had full twenty years priority over any one else except Mendel in the recognition of the principle" (Whitson et al., 1914, 1915, p. 199).

However, Burbank still believed that there was a "misapprehension as to the real significance of 'unit characters', and who, misguided by a narrow range of experiments, and lacking the breadth of view that comes with wider experience, have supposed that all heritable characters might be classified as fixed and unvarying entities that are transmitted in accordance with the Mendelian formula" (Whitson et al., 1914, 1915, p. 200). In this, he seems to be making a point about polygenic traits "that do not Mendelize in any tangible or demonstrable way" (p. 200). He also thought that Mendel's "unit characters" were composed of "subordinated characters" and that new "unit characters" appear at various times and that the old "unit characters" would then no longer follow Mendelian heredity. To follow this, he wrote: "So Darwinian heredity, which recognizes the heritability of whole coteries of characters that are too profoundly fixed to Mendelize, is again receiving recognition" (p. 202).

INTERSPECIFIC HYBRID WALNUTS

"I had heard of a supposed natural European hybrid walnut, and I determined to make the experiment of fertilizing the flowers of the California species with pollen from the Persian" (Whitson et al., 1914, 1915,

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p. 138). The California walnut species has since been identified as *Juglans hindsii* (Lucker, 1996). Thus was born the idea leading to crossing *J. hindsii* with both *J. regia* and *J. nigra*. However, it was controversial when he first made the crosses.

Burbank stated that when his *New Creation in Fruits and Flowers* catalog was published in June 1893, the hybrid walnuts were 5 or 6 years old and the 'Royal' had borne fruit, but not the 'Paradox' (Whitson et al., 1914, 1915). Allowing time for stratification, the crosses were therefore made in 1886 or 1887. Howard (1945, p. 39) wrote that Burbank stated in this same catalog: "This hybrid originated in 1888 from a cross made the year before" corroborating the 1887 date. Therefore, it would appear clear when Burbank first hybridized walnuts. However, Howard (1945) wrote that the walnut interspecific crosses were made earlier, from 1878 to 1885, and that his first hybrid was in 1878 and was between *J. hindsii* × *J. regia* and the next year the first hybrid was obtained from *J. hindsii* × *J. nigra*. He further added that Burbank's mention of 1888 in his 1893 *New Creations in Fruits and Flowers* catalog was a printing error.

Dr. George H. Shull, a geneticist from Princeton University, spent from 1906 to 1911 in Santa Rosa, CA, as a representative of the Carnegie Institution of Washington, which had bestowed a large grant to Burbank. Shull's duty was to control the activities of Burbank and collect and record all of the information that he could gather on previous achievements. This was warranted because although Burbank's creations were valuable and famous, his notes were rudimentary (Janick, 2015) and deserved better documentation.

In a letter dated May 12, 1943, Shull quoted from his unpublished report on Burbank's activities: "In 1877 Mr. Burbank applied pollen of the Persian to a tree of California black; the nuts were stratified and planted (1878) with the result that among a very large number of obviously pure California blacks, "some 5 or 6" were plainly hybrids. There was some variation in size and vigor, and only the finest and largest one was retained for propagation, and this was the first Paradox. Two of the other hybrid seedlings were sent to the Sebastopol grounds where they served as stocks for numerous Persian grafts" (Howard, 1945, p. 40). Topworked walnuts can still be identified at the Gold Ridge Luther Burbank Experiment Farm (Fig. 1).

With such a contradiction among the dates reported by Burbank, Howard, and Shull, it is difficult to determine the exact timing of his first interspecific walnuts. One would think that Burbank would be correct, but because of his fractured notes, Dr. Shull may indeed have the real date. This seems corroborated by the sign (Fig. 2, inset) at the Gold Ridge Luther Burbank Experiment Farm in Sebastopol, CA, which states that the 'Royal' tree there was planted in 1885 meaning that the cross that resulted in this F_1 tree was made before or during 1884, before the 1887–88 dates reported by Luther Burbank.

'PARADOX' WALNUT

Burbank found that seedlings of a *J. hindsii* × *J. regia* cross were much more vigorous than seedlings of either species (Whitson et al., 1914, 1915; Fig. 3) and that this very rapid growth rate was sustained from year to year. For a walnut tree to grow to 18.3 m (60 ft) in 16 years was truly extraordinary because hardwood trees were known to grow slowly. A fast-growing hardwood was a paradox, and indeed this and the fact that the hybrid manifests several traits of one parent over the other, rather than a blending of traits, was why Burbank named his hybrid by this name.

'Paradox' is a shy producer of thick, hard nuts that resemble rough-textured Persian walnuts. Burbank was able to germinate enough of the few seeds that it produced to observe giants and dwarfs in the F_2 generation (Whitson et al., 1914, 1915)

Another anomaly of Burbank's 'Paradox' walnut is its very long leaves, some reaching 1 m (3 ft) long with an "apple-like fragrance" (Whitson et al., 1914, 1915). As first observed by Burbank, the leaves on 'Paradox' trees are similar to those on Persian walnut as is the bark. Burbank wrote about using 'Paradox' seedlings for rapid production of fine hardwood that could be used for cabinetry (Whitson et al., 1914, 1915), but this never caught on.

By 1912, Smith et al. (1912) had tested seedling 'Paradox' as walnut rootstocks. They were disappointed with the results of grafting onto F_2 'Paradox' but were pleased with the "unusual" vigor of the walnuts grafted onto F_1 'Paradox' rootstocks. They discussed the higher cost and care of producing the F_1 'Paradox' seedling rootstocks compared with black walnut rootstocks or Persian walnut on its own roots. They and other pomologists of the time were testing 'Paradox' as a rootstock and that was the beginning of the use of what was to become the most popular rootstock in California. This is because of 'Paradox' vigor, some *Phytophthora* crown and root rot resistance, and some resistance to root lesion nematode (Fig. 4). The majority are F_1 hybrid seedlings of *J. hindsii* × *J. regia*. *J. hindsii* is the female parent used by modern nurseries for production of seedling 'Paradox' rootstock (Fig. 5). Seedlings that germinate from the stratified black walnuts are a mixture of 'Paradox' and pure *J. hindsii* that are easy

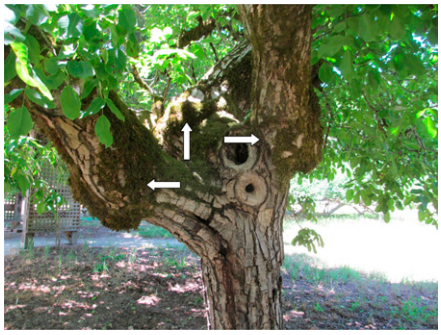

Fig. 1. Topworked walnut at the Gold Ridge Luther Burbank Experiment Farm. Luther Burbank topworked his walnuts to accommodate more *J. regia* nut cultivars for his crosses on fewer trees. A photograph of his much younger topworked walnuts appears in Whitson et al. (1914, 1915, p. 161).

Fig. 2. 'Royal' walnut tree on the grounds of the Gold Ridge Luther Burbank Experiment Farm in Sebastopol, CA, that was 128 years old when photographed in 2013. For scale, the fence is 6 feet (nearly 2 m) tall. Inset shows sign directing visitors to the 'Royal' Walnut tree with planting date.

Fig. 3. 'Paradox' walnut trees on the grounds of the Luther Burbank Home & Gardens, Santa Rosa, CA. When this photograph was taken in 2013, the older tree on the left was 99 years old its original top was no longer present. The 'Paradox' tree on the right (arrow) was ≈20 years old.

Fig. 4. A walnut orchard grafted onto 'Paradox' rootstock. The 'Paradox' manifests the dominant smooth bark trait from its Persian walnut paternal parent, making the graft unions (arrows) not as obvious as when grafted onto black walnut rootstock.

Fig. 5. The right scaffold of this tree was grafted with *J. hindsii,* whereas the left scaffold is *J. regia* in this commercial 'Paradox' seed orchard. Black walnut is used as the female parent to facilitate rouging nonhybrid walnuts from 'Paradox' seedlings in the nursery bed. It is necessary to have a few Persian walnuts in the seed orchard as pollen sources.

Fig. 6. This closeup of the 'Royal' tree in Fig. 2A shows its heavy production of nuts. This tree still produces nearly 907 kg (1 ton) of nuts each year (Wiesler, 2012).

to distinguish by leaf texture. If *J. regia* were used as the seed parent, it would be more difficult to visually separate from and rogue non-'Paradox' seedlings.

Three clonal 'Paradox' walnut rootstocks are available today through micropropagation. Two of the clonal rootstocks are traditional 'Paradox' F_1 hybrids of *J. hindsii* × *J. regia*: 'Vlach' imparts vigor to the scion and 'VX211' imparts vigor and lesion nematode tolerance. 'RX1' is a new type of 'Paradox' because it is an F_1 hybrid between *J. microcarpa* (Texas black walnut) and *J. regia* that has resistance to *Phytophthora*. 'Paradox' rootstock development is now focused on creating various *Juglans* interspecific hybrids to incorporate increased resistance to soilborne pathogens and adaptability to various soil conditions. Today superior rootstock genotypes can be cloned using micropropagation, ensuring a more uniform phenotype for the grower.

'ROYAL' WALNUT

At around the same time that Burbank created 'Paradox' walnut, he also made the *J. hindsii* × *J. nigra* cross that resulted in the 'Royal' walnut (Whitson et al., 1914, 1915; Fig. 2A). Similar to the 'Paradox' hybrid, this F_1 hybrid grew extremely rapidly and the F_2 generation segregated, producing both giants and dwarfs.

A striking difference between 'Royal' and 'Paradox' walnuts is that 'Royal' produces large seed crops. Burbank wrote: "At sixteen years of age one of these trees produced a harvest of nuts that filled twenty apple boxes, each about two feet long by one foot in width and depth. In one year I sold more than a thousand dollars worth of nuts from a single tree" (Whitson et al., 1914, 1915, p. 146). The 'Royal' tree, planted in 1885, continues to produce large seed crops at Gold Ridge Luther Burbank Experiment Farm in Sebastopol, CA (Figs. 2 and 6). The nuts are similar to black walnuts but bigger. Trees in the F_2 generation may not be good producers of nuts (Whitson et al., 1914, 1915).

Although California walnuts are not grafted onto 'Royal' rootstocks today, Burbank was a proponent of such use. He reported that Persian walnut grafted onto 'Royal' produced much larger nut crops and that blight was less of a problem when compared with Persian walnut on its own roots (Whitson et al., 1914, 1915). Luther Burbank recommended planting seeds of the 'Royal' hybrid and then selecting the strongest growers from the segregating F_2 generation. He then recommended allowing the rootstocks to grow for 4 to 5 years to a trunk caliper of 3 to 6 inches (7.5 to 15 cm) before grafting. Today, using modern nursery practices, F_1 'Paradox' seedlings are grafted within the first 2 years onto trees with a 1-inch (2.5-cm) caliper.

JAPANESE WALNUT HYBRIDS

Burbank crossed Japanese walnut (*J. Sieboldii*, now *J. ailantifolia*) with *J. regia*. Similar to his other walnut hybrids, this one grew rapidly (Whitson et al., 1914, 1915). It produced few nuts and the nuts were intermediate between the parents. The leaves were much larger and more pubescent than either parent and the bark was white. The nuts were very hard and the great-tasting meat was difficult to extract from the shell. This hybrid is no longer grown.

SCION BREEDING

Similar to walnut breeders today, Luther Burbank selected for "early and abundant bearing, whiteness and palatability of meat, and absence of tannin—it being tannin which gives the brown color and bitter taste to the older and ordinary walnuts" (Whitson et al., 1914, 1915, p. 37). However, he also selected for thin-shelled walnuts, also known as soft shells or paper shells. He pointed out that shells of Persian walnut are already thin-shelled compared with the native black walnuts of North America, but sought to improve on this trait.

This included breeding paper-shelled walnuts that can be cracked with bare fingers, making them easy to eat. However, because of poor shell strength, they do not handle or ship well. Burbank developed a walnut that had such a thin shell that birds could easily peck through it (Whitson et al., 1914, 1915). He also mentioned a "nut that had a mere rim of shell, being thus comparable to the stoneless plum" (Whitson et al., 1914, 1915, p. 36). Because of predation and shipping problems, he returned to a somewhat thicker shell in his breeding.

He selected and named the 'Santa Rosa Soft-Shell' walnut. Mr. Alfred Wright told Luther Burbank about the parent tree that was growing in San Francisco (Whitson et al., 1914, 1915). Burbank said that the tree produced nuts of extremely high quality but with poor suture closure, leading to storage problems compared with nuts with sealed sutures. He collected nuts from the original tree shortly before it was destroyed to provide room for a street. It was from these seedlings that he selected 'Santa Rosa Soft-Shell.' This seedling was selected for cloning because although the nuts are medium size, they are ready for harvest ≈3 weeks earlier than other walnuts grown at the time in California (Whitson et al., 1914, 1915). The taste was said to be delicious and the meat of the nut white. He especially liked that it produced large crops, but it could be damaged by late spring frosts. This cultivar is no longer grown.

CONCLUSION

Although Luther Burbank thought that 'Paradox' walnut was best grown for its wood, today it is the most used walnut rootstock in California. The use of the F_1 hybrids as rootstocks bypassed the variation and additional selection required of the F_2 generation. Therefore, nurseries have orchards, primarily of *J. hindsii* with a few *J. regia* interplanted or grafted onto the black walnuts. The black walnut seeds are collected, sown in nurseries, and the black walnuts are rogued, leaving the 'Paradox' to be used as rootstock. Micropropagation has allowed for commercial production of three clonal 'Paradox' rootstocks moving 'Paradox' in a direction unimagined by Luther Burbank. 'Royal' and Japanese × Persian walnut hybrids are not grown commercially. Although Burbank selected for many of the same traits as modern walnut breeding programs, the 'Santa Rosa Soft-Shell' has been replaced with improved walnut cultivars.

Burbank's contributions to walnuts are substantial and long-lasting. Walnut rootstock breeders especially stand squarely on his shoulders as they incorporate genes from walnut wild relatives into interspecific hybrids and select for tolerance or resistance to various soil conditions, including pathogens.

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